California High-Speed Rail Project

CALIFORNIA
High-Speed Rail Authority

California High-Speed Rail Benefit-Cost Analysis (BCA)

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1.0 - Introduction

This report is an economic benefit-cost analysis of the complete Phase I of California High Speed Rail Project (CA HSR) conducted for the California High Speed Rail Authority (Authority). It estimates benefits and costs for all segments through the completion of Phase I as defined in this Business Plan. This analysis was completed in support of the 2012 Business Plan, and conducted in accordance with the benefit-cost methodology as recommended by the US DOT in the Federal Register (75 FR 30460) *(1).*

2.0 - Key Analytical Assumptions

2.1 - Real Discount Rate

Benefits and costs are typically valued in constant (e.g., 2010) dollars to avoid having to forecast future inflation and escalate future values for benefits and costs accordingly. Even in cases where costs are expressed in future, year of expenditure values, they tend to be built upon estimates in constant dollars, and are easily deflated. The use of constant dollar values requires the use of a real discount rate for present value discounting (as opposed to a nominal discount rate).

A real discount rate measures the risk-free interest rate that the market places on the time value of resources after accounting for inflation. Put another way, the real discount rate is the premium that one would pay to have a resource or enjoy a benefit sooner rather than defer it until later. For example, most people would prefer to be given $10,000 now, as opposed to ten years in the future. This is especially true because that amount of money, if invested now, would likely yield more than $10,000 ten years from now. As such, the values of future resources must be discounted.

For CA HSR investments, dollar figures in this analysis are expressed in constant 2010 dollars. In instances where certain cost or benefit estimates were expressed in dollar values in other (historical) years, the Bureau of Labor Statistics' Consumer Price Index for Urban Consumers (CPI-U) for 2010 was used to adjust.

Choosing an appropriate discount rate is essential to appropriately assessing the costs and benefits of a project. The higher the discount rate, the lower the present value of future cash flows. For typical investments, with costs concentrated in early periods and benefits following in later periods, raising the discount rate tends to reduce the net present value or economic feasibility of the investment.

The real discount rate this analysis uses for evaluating the CA HSR project is 4.0 percent.

This 4 percent discount rate is consistent with US DOT guidance for TIGER II grants and OMB Circular A-4 and A-94 *(2)(3)*. While the U.S. DOT recommends the use of a 7.0 percent discount rate as a baseline, a lower discount rate can be used when the project is being funded with public funds.

The rationale is that private corporations will tend to invest in riskier and higher-yield investments, thus having a much higher opportunity cost. Public entities, however, will tend to maintain investments that are much more conservative in yields, and have opportunity costs more in line with that of government bonds than private securities. While a discount rate as low as 3 percent is justifiable, this BCA utilizes a slightly more conservative 4 percent discount rate, which is also consistent with the BCA conducted for CA HSR by Cambridge Systematics *(4).*

2.2 - Evaluation Period

Benefits and costs are typically evaluated for a period that includes the construction period and an operations period ranging from 20-50 years after the initial project investments are completed. Given the permanence and relatively extended design life of high-speed rail investments, longer operating periods, and thus, evaluation periods are often used.

For the CA HSR BCA, the evaluation period includes the relevant (post-design) construction period during which capital expenditures are undertaken, plus 40 years of operations beyond project completion within which to accrue benefits.

For the purposes of this study, there were four scenarios considered. Depending on the scenario, the construction period would vary. Scenarios ranged from the entire Phase I of CA HSR being completed by 2033 to 2038, with other segments coming on-line at different points in earlier years. For the purposes of analysis, all scenarios assumed that post-design construction begins in 2013. Accordingly, this analysis examines all benefits and costs for an analysis period from 2013 to 2080, which is approximately 42 years beyond project completion for the scenario with the longest construction period.

As a simplifying assumption, all benefits and costs are assumed to occur at the end of each year, and all benefits begin in the annual year immediately following the final construction year.

2.3 – Project Region and Phasing

The geographic coverage of this CA HSR BCA is considered to be the entire state of California. Thus, benefits are the cumulative effects across the entire state.

While this analysis examines "Phase I" of the CA HSR project, this actually comprises of various steps, namely:

- Initial Construction Section (ICS)
- Initial Operating Segment – North (IOS North)
- Initial Operating Section – South (IOS South)
- Bay to Basin (non arithmetical accumulation of the three sections above)
- Phase 1 (system built out with connections to San Francisco and Anaheim)

In order to conduct a BCA, some assumptions about timing of phasing had to be made. First, this analysis assumes that the sequence of construction will be as outlined above: 1) ICS, 2)IOS North, 3) IOS South (i.e. "Bay to Basin"), and 4) Phase I Completion. While it is possible that IOS South may be constructed before IOS North (the two may be interchangable), this assumption had to be made in order for analysis to be possible. However, this assumption does not constitute an endorsed course of action by the Authority, and it is simply made in order for analysis to be possible given existing uncertainty of construction sequencing.

For the same reasons, the timing of these phases had to be defined becaues a BCA depends on defining when expenditures occur and when they begin. The phasing of the construction costs, outlines the start date of ICS as 2013, and the completion dates for the subsequent segments as illustrated in Table 1. Again, this does not constitute an endorsement by the Authority, and this schedule is only a set of assumptions made solely for analysis purposes.

Table 1. California HSR Phasing Assumptions for Benefit-Cost Analysis, Year of Completion for Sub-phases

Sub-phase	Scenario 1	Scenario 2
ICS	2017	2017
ICS + IOS North	2021	2022
ICS + IOS North + IOS South (Bay to Basin)	2026	2027
ICS + IOS North + IOS South (Bay to Basin) + completion of Phase I	2033	2038

Source: 2012 Business Plan

There are two scenarios examined in this BCA:

- Scenario 1, which assumes all of the lowest-cost alternatives
- Scenario 2, which assumes all of the highest-cost alternatives

The low-cost scenario indicates a construction cost of approximately $65.2 billion and the high-cost scenario includes construction capital costs of approximately $74.2 billion. However, the bottom-line costs used for B/C ratios excludes the costs of real estate, which are considered an asset investment (discussed later).

2.4 - Travel Demand Sources and Forecast Years for Highway Benefits

2.4.1 Travel Demand Models

The travel demand model in Table 2 includes a base year 2009, as well as estimates for 2040. This modeling incorporates the fact that the CA HSR project will reduce vehicle-miles and vehicle-hours on the highway network as travelers switch to HSR

Table 2. Base Travel Demand Model for California Highways and Roads, 2009 and 2040

		Vehicle Miles Traveled (annual)	Vehicle Hours Traveled (annual)
2009	No Build	324,275,000,000	9,547,868,000
2040	No-Build	516,780,435,942	15,215,947,537
	Build	511,379,787,110	15,096,158,491
	% Savings per million riders	0.028%	0.021%

Source: CA HSR Travel Demand Model

To extrapolate the travel demand model, a 1 percent growth rate was used up to 2030, and a 0.5 percent growth rate was used from 2030 onwards.

However, this travel demand model in Table 2 formed only the raw basis of a modified travel demand that reflects sub-phasing indicated above. In order to adjust travel demand to reflect this phasing, HSR ridership data was utilized (see Business Plan Chapter 6).

Table 3. HSR Ridership for 2040, Scenario 1

Scenario	**2040 Total Ridership (millions)**
IOS North	14.66
Bay to Basin	23.76
Phase 1	37.00

Source: CA HSR Travel Demand Model

Table 3 provides the ridership data for 2040 assuming that each of the reflected sub-phases are built at that point. In developing the ridership model, growth rates were assumed to be 1.0 percent up to year 2030, and 0.5 percent beyond 2030. A ridership time-series was built using these ridership data and growth rate assumptions, along with respective phasing schedules. That is to say, the marginal ridership of any given phase was not realized until the construction of that phase was completed for the given scenario.

Marginal ridership is the additional riders that are expected from the completion of a new sub-phase. For example, in Table 3, the cumulative ridership for Bay to Basin is 23.76 million in 2040. However, the marginal ridership is only 9.1 million because the cumulative ridership had included the ridership of the sub-phase preceding it.

Furthermore, ridership for each sub-phase was progressively ramped up over 5 years, such that 40 percent of marginal ridership was realized in the first year; 55 percent in the second year; 70 percent in the third year; 85 percent in the fourth year; and 100 percent of ridership is realized in the fifth year and beyond.

Knowing the ridership, and having a “no build” time series, it was possible to construct a “build” time series by identifying VMT and VHT savings. Certain factors were utilized for this. Based on the travel demand model and ridership (see Table 2), it was calculated that there was a VMT savings of 0.028 percent for every million HSR riders; and a VHT savings of 0.021 percent for every million HSR riders. This was calculated by dividing the total VMT savings (as percent of no-build VMT) by projected ridership in 2040.

Using the time series of phased-in HSR ridership, and the base “no build” ridership time series, VMT and VHT savings were calculated using these factors. Thus, a build and no-build time series of VMT and VHT was built and utilized.

In order to not “double count” travel time savings that are experienced by riders who shift modes from automobile to HSR, adjustments were made to the total VMT and VHT that excluded those savings that VMT and VHT of new HSR travelers.

3.0 - Economic Benefits Included

The following identifies and groups the benefits that are included in the BCA for the CA HSR.

3.1 Economic Competitiveness

3.1.1 - Travel Time Savings

Value of Time Assumptions

Travel time savings in this BCA includes two categories: 1) in-vehicle travel time savings for auto passengers and truck drivers, and 2) travelers who transfer from auto to HSR and subsequently experience travel time savings.

Travel time is considered a cost to users, and its value depends on the disutility (cost or disbenefit) that travelers attribute to time spent traveling. A reduction in travel time would translate into more time available for work, leisure, or other activities, which travelers’ value.

Travel time savings must be converted from hours to dollars in order for benefits to be aggregated and compared against costs. This is traditionally performed by assuming that travel time is valued as a percentage of the average wage rate, with different percentages for different trip purposes. For this analysis, assumptions for value of time (VOT) estimates were derived from U.S. DOT recommended values *(5 p. 4).*

This process typically involves valuing travel time for a work commute trip higher than a trip for non-work (any discretionary trip). However, trip information is not available explicitly by trip purpose in the travel demand models. Utilizing data from the National Household Travel Survey *(6)* for the state of California, vehicle-miles across the state can be disaggregated by peak and off-peak hour, and subsequently by trip purpose. These figures allow for the disaggregation of travel demand model results, as well as the development of individual values of time.

From the National Household Travel Survey 2009, the following information is known about California:

- 52.55 percent of all VMT occurs in the peak hours from 6:00-10:00 AM and 3:00-7:00 PM.
- 47.45 percent of all VMT occurs in the off-peak hours.

The standard wage rate used comes from the Bureau of Labor Statistics for the state of California. This analysis uses the 2010 average wage rate for all private employees, which is $26.39 per hour.

The U.S. DOT *(5 p. 4)* accepts the use of 100 percent of the local wage rate as the value of time for work-related trips, and 50 percent of the local wage rate as the value of time for non-work trips. Using this, the following assumptions are used for valuing travel time savings as expressed in real 2010 dollars.

- **Peak Period Travel** — 16.6 percent of trips in the peak period are work-related; 83.4 percent of peak-period trips were non-work related *(6)*. This creates a weighted peak-period passenger VOT of $15.38.
- **Off-Peak Period Travel** — 22.2 percent of trips in the off-peak period are work-related; 77.8 percent of off-peak trips were non-work related *(6)*. This creates a weighted off-peak period passenger VOT of $14.72 per hour.

For Aviation passengers, the U.S. DOT suggests a plausible range between 60 to 90 percent of the local wage rate for intercity airline leisure travel, and 80 to 120 percent for business travel *(5 p. 4)*. This analysis assumes a value of time of 90 percent of the local wage rate for leisure travelers, and 120 percent for business travelers. This analysis also assumes that 20 percent of aviation passengers consist of leisure traveler. The resulting weighted value of time used for aviation passengers is $30.08 per hour.

For HSR passengers, a similar logic was used as for aviation passengers. However, the values of time were assumed to be slightly lower. Leisure travelers were assumed to have a value of time equal to 80 percent the local wage rate, and business travelers were assumed to have a value of time at 110 percent the local wage rate. The resulting weighted value of time used for HSR passengers is $27.45 per hour.

Aviation and HSR values of time are slightly higher than the wage rate because values of 120 and 110 percent of the value of time were used for business travelers.

Commercial Trip Assumptions

It is acknowledged that commercial trips tend to have a much higher value of time than personal travel. The cost of the driver's time represents the minimum opportunity cost for the business owner for travel delays in freight movement. The true value of time lost or saved for a commercial trip relates to the cargo and increases if the cargo is perishable or very high value added commodity. This analysis does not differentiate traffic by commodity and uses the Bureau of Labor Statistics wage rate for the "transportation and utilities" industry in California as a proxy for the truck VOT. Commodity delays, thus, are excluded from the calculations and the wage rate is used as a proxy.

The value of time used for trucks in this analysis is 100 percent of that wage rate, or $23.65 per hour in 2010 dollars.

Further, for travel demand calculations it is assumed that 7.1 percent of all trips are truck trips, consistent with the California Department of Transportation's Traffic Counts of their State Highway System *(7).*

Value of Time Real Growth Assumptions

Historically, wages and salaries have increased, on average, at a higher annual rate than general price inflation. Thus, the VOT should increase as well. Increases in the level of wage and salary incomes per job above and beyond general inflation are referred to as real increases. However, this analysis conservatively assumes a constant VOT in real 2010 dollars.

Average Vehicle Occupancy Assumption

Because travel time savings are incurred per individual person, not vehicle, it is necessary to identify the number of person-hours traveled as opposed to the vehicle-hours that travel demand models produce.

In order to do this, this analysis assumes an average vehicle occupancy (AVO) rate of 1.64 persons per vehicle for local trips, and 1.92 persons per vehicle for intercity trips. This AVO rate is adopted from the National Household Travel Survey 2009's data for California for all trips *(6).*

3.1.2 - Reliability Benefits

Reliability in travel times is an important element of user benefits from a system like CA HSR. Relative to a highway trip, travelers can generally expect a more reliable trip with trains arriving on time and per a schedule, rather than being subject to the random delays that can occur on the highway network. High speed trains, in particular, have been proven to operate an extremely reliable system.

Because users come to expect, and adjust to, delays on the highway network, there is some extra time spent on a trip in order to compensate for the additional time spent. This "buffer time" is that extra lead time and it can be expressed by a concept known as the "Planning Time Index", which is a measure of the amount of the amount of actual time spent on a trip after incorporating a certain buffer period above and beyond the standard travel time. This concept is not incorporated in the standard travel demand models, and it can be calculated based on historical data for metropolitan regions.

The Texas Transportation Institute's Urban Mobility Report has measured the Planning Time Index for four cities in California *(8 p. B.53):*

Table 4. Planning Time Indices in California

Region	Planning Time Index in Average Conditions
Los Angeles	1.47
Sacramento	1.26
San Francisco	1.25
Orange County	1.40

Source: Texas Transportation Institute

A Planning Time Index for Los Angeles of 1.47 means that for the average trip, users will incorporate 47 percent extra "buffer time" into their trip to account for the unreliability of the highway network. Thus, a traveler who intends that his trip may take 20 minutes will add an additional 9.4 minutes as a buffer.

This analysis used a Planning Time Index of 1.30 based on the information above.

When travelers switch from highway trips to new HSR service, it is assumed that they no longer plan that additional buffer time for the new trip. Knowing the number of trips transferring from automobile to HSR; the average speeds on the highway network; and assuming the HSR trip and highway trip are equivalent distances, it is possible to estimate the buffer time saved. This travel time, when monetized using value of time, represents reliability savings.

3.1.3 - Reductions in Vehicle Operating Costs

The proposed CA HSR investments would not only affect travel times, but they would also reduce vehicle operating and ownership costs overall. They would do so because travelers would shift towards the HSR service, reducing the total amount of VMT on the roadway system relative to the "no build" situation.

As a consequence, vehicle and truck operating costs that are linked to mileage will decrease. In other words, driving fewer miles leads to lower costs of operating the vehicle.

Vehicle Operating Costs - Fuel

The first operating cost reduction the CA HSR BCA calculated was the reduction in fuel costs. This analysis utilizes the Energy Information Administration's (EIA) Annual Energy Outlook 2011 projections for auto, truck and jet fuel efficiency (for aviation use), as well as the price of gasoline, diesel, and jet fuel *(9)(10).*

The EIA only projects figures to 2035, so it was necessary to further project for years 2036 to 2080. Based on the EIA's "reference case," this analysis projected fuel efficiency and prices based on the compound annual growth rate (CAGR) in the EIA's model for 2010 to 2035. Further, because the EIA expresses fuel prices in 2009 dollars, CPI-U was utilized to adjust fuel prices to 2010 dollars. Table 5 outlines the range utilized.

Table 5. Fuel Economy and Fuel Prices – 2010 (est.) and 2040 (Projected)

	2010 (est.)	2040 (projected)
Auto Fuel Economy	20.8 miles per gallon	29.1 miles per gallon
Truck Fuel Economy	6.1 miles per gallon	6.7 miles per gallon
Jet Fuel Economy	62.1 seat-miles per gallon	72.2 seat-miles per gallon
Gasoline Price	$2.73 per gallon (2010 $)	$4.02 per gallon (2010 $)
Diesel Price	$2.94 per gallon (2010 $)	$4.20 per gallon (2010 $)
Jet Fuel Price	$2.16 per gallon (2010 $)	$3.81 per gallon (2010 $)

Source: U.S. Energy Information Administration

Vehicle Operating Costs – Non-Fuel

Non-fuel operating costs include the cost of operations and maintenance to vehicles, the cost of tires, and vehicle depreciation. A reduction in VMT due to project investments results in cost savings in these categories. The per-mile values of these categories were derived from a study conducted by Barnes and Langworthy *(11).* This analysis their "baseline costs" which reflected the most conservative estimate of operating costs because it assumes highway conditions and smooth pavements (see Table 6).

Table 6. Non-fuel Operating Cost Assumptions

Operating Cost Category	Cost per Vehicle-mile Traveled (2010 $)
Auto - Maintenance/Repair	4.1 cents per VMT
Auto – Tires	1.1 cents per VMT
Auto – Depreciation	7.9 cents per VMT
Truck – Maintenance / Repair	12.4 cents per VMT
Truck – Tires	4.1 cents per VMT
Truck – Depreciation	9.5 cents per VMT

Source: Barnes and Langworthy, 2003.

This analysis uses these average costs per mile values to calculate variable non-fuel vehicle operating costs.

3.1.4 - Reductions in the Economic Cost of Oil Imports

Fuel consumption has a cost beyond the actual operating costs or the environmental costs of the consumption which is expressed as the economic cost of oil imports. This concept reflects two ideas: a monopsony component and a price shock component.

The monopsony component suggests that because the U.S. is such a large consumer of oil that an increase in U.S. oil demand will lead to higher fuel prices (based on supply and demand relationships). The price shock component suggests that a reduction in oil supplies leads to higher oil prices thereby reducing the level of U.S. economic output. As a consequence, reducing oil imports by consuming less fuel reduces these costs on the U.S. economy. The National Highway Traffic and Safety Administration *(12 pp. viii-22 – viii-27)* suggests that each gallon of fuel saved reduces total U.S. imports of refined fuel or crude oil by 0.95 gallons.

This analysis uses NHTSA's *(12)* estimate for the per gallon cost of oil imports for the monopsony and price shock components, which is $0.41 per gallon in real 2010 after CPI-U adjustment.

3.1.5 – Productivity Benefits

Productivity benefits refer to the idea that travelers are capable of being productive on the new HSR service, whereas they were incapable of the productivity while driving, and less likely to be productive when on an aircraft. For example, an automobile traveler who diverts his or her 90 minute trip to a HSR trip is now capable of using his or her laptop, making phone calls, and continue being productive on the train. While driving, conducting work would be nearly impossible; and completing work would be less likely on the plane. Thus, these productivity benefits are from in-transit productivity.

It is assumed that zero percent of automobile travelers are productive in-transit; 33 percent of airline travelers are productive in-transit; and 50 percent of HSR travelers are productive in transit.

Because the number of transfers from other modes onto HSR is estimated from travel demand models, as well as total in-transit travel times, it is possible to calculate the differential in productivity time of those travelers in a world where they do not have HSR versus a world where they do.

These additional hours of traveler productivity from those users transferring to HSR service can be monetized using values of time discussed above.

3.1.6 – Reduction in Parking Infrastructure Needs

When automobile travelers shift to HSR, this reduces the need for parking infrastructure to meet the demands of those vehicles. Since it is estimated how many vehicle trips will transfer from automobile to HSR, the number, and value of those parking spaces can be estimated as well.

It is assumed that for every 365 vehicles taken off the road each year, one less parking space is needed somewhere to suit that vehicle. In other words, one parking space can serve one car for one day for 365 days a year.

Second, it is assumed that 50 percent of the parking demand would be in surface spaces, while the remaining 50 percent would be in structured parking.

Finally, the cost of each parking space is estimated at $300 per surface space, and $1,000 per structured space. These estimates are moderate estimates from a range provided by the Victoria Transportation Institute *(13 p. Table 6)*. Given these assumptions, it is possible to then calculate the reduction in parking infrastructure needs, in dollars.

3.1.7 – Airline Operator Savings

As travelers shift modes from airport towards the new HSR service, this has the effect of relieving congestion and reducing delay in the region's airports. As a result, operators benefit from these delay reductions.

The travel demand model provides an estimate of intrastate air passenger trips in 2040 assuming a completed HSR system through Phase I.

Table 7. Travel Demand Model for Intrastate Aviation – 2040

	No-Build	Build
Air Passenger Trips	32,725,146	24,656,579
Air Passenger Trip Reduction	-	8,068,566
Air Passenger Trip Reduction %	-	24.7%
HSR Ridership estimate	-	37.0 million

Source: Parsons Brinckerhoff

The model in the figure above was used to calculate two sets of data: 1) a time series of air passenger trips in the "no build" scenario, and 2) a factor of 0.70 percent reduction in air travel for every million HSR riders in that year (24.7% / 37.0 million). This factor was used later.

Using Bureau of Transportation Statistics and Federal Aviation Administration *(14)* data for 2010 California departing flights, it was calculated that there were 720,732 departing flights; 72,042,237 departing passengers; and 7,681,411 minutes of delay. This translated to:,

- 99.6 passengers per flight
- 10.7 minutes of delay per flight

These flight figures were used to convert the number of passenger trips into minutes of flight delay:

Second, this analysis calculated a delay elasticity utilizing historical information for California originating flights from the same Bureau of Transportation Statistics and FAA data. Using an econometric model, this analysis calculated that for every 1 percent reduction in flights, there is a 0.956 percent reduction in delay, holding load factor constant.

Having calculated the no-build flights, no-build delay, and an estimate of build flights based on HSR ridership, the reduction in delay (and thus no-build delay) was estimated using this elasticity.

This reduced aviation flight delay (in aircraft minutes) was monetized using the Air Transport Association's *(15)* estimate of $36.09 non-fuel costs per minute of aircraft delay.

3.1.8 – Propagated Air Delay

Aircraft delay does not contain itself to one airport or one region. Instead, delay at airports is propagated across the entire air system. A MITRE Corporation report for the FAA *(16)* calculates propagation multipliers that estimate the amount of delay incurred at other airports in the system due to delay at one airport. In 2008, for SFO, the delay propagation multiplier was 1.55; for LAX it was 1.50.

What this means is that for every 100 hours of delay at LAX, there were 150 hours of delay across the entire system. Thus, the marginal delay propagated to the rest of the system is 50 hours.

This analysis uses a delay propagation multiplier of 1.50, and applies it to the operator delay costs calculated above.

3.1.9 – Airline Fuel Savings

Having calculated the number of flights saved due to mode shift to HSR, airline fuel savings can be estimated. First, it is estimated that the average flight distance for an intra-state flight departing from California is 400 miles. FAA data also indicates that there were approximately 127 seats per flight in 2010 for California departing flights. Combined, these numbers yield the total number of seat-miles.

Using the EIA's estimate *(9)(10)* of jet fuel efficiency (seat-miles per gallon) and jet fuel costs (2010 $ per gallon) both the quantity of fuel and the value of the fuel saved can be calculated.

3.1.10 – Air Passenger Delay

In addition to airline operators, passengers in the aviation system also experience costs of delay. When flight delay is reduced, passengers experience air passenger delay benefits.

Flight delay and flight delay savings were already calculated above. A NEXTOR study *(17)* had calculated passenger delay as it relates to total flight delay, and certain factors can be derived for the overall aviation system:

- 1.06 minutes of "non-disrupted passenger" delay per minute of flight delay.
- 31.19 minutes of "disrupted passenger" delay per minute of flight delay.

In this context, "disrupted" passengers refer to those passengers who have their flights canceled or miss a connection due to flight delay. "Non-disrupted" passengers are those passengers who still make their flight and connection, but their flight is delayed and not on schedule.

Using these factors, air passenger delay can be derived from the total flight delay calculated above. This is monetized using value of time assumptions discussed previously.

3.2 - Safety

3.2.1 – Accident Cost Savings

Reductions in VMT lower the incidence of traffic accidents. The cost savings from reducing the number of accidents include direct savings (e.g., reduced personal medical expenses, lost wages, and lower individual insurance premiums) as well as significant avoided costs to society (e.g., second party medical and litigation fees, emergency response costs, incident congestion costs, and litigation costs). The value of all such benefits – both direct and societal – could also be approximated by the cost of service disruptions to other travelers, emergency response costs to the region, medical costs, litigation costs, vehicle damages, and economic productivity loss due to workers inactivity.

The state-of-the-practice in B/C analyses is to estimate accident cost savings for each of three accident types (fatal accidents, injury accidents, or property damage only accidents) using the change in highway VMT. Some studies perform more disaggregate estimates of the accident cost savings, applying different accident rates to different types of roadways (e.g., interstate, highway, arterial).

This BCA estimates the benefits associated with accident cost savings using 2009 statewide accident data reported by the California Highway Patrol *(18 p. Sec 1).* The accident figures are statewide averages and represent accidents on interstate highways, state highways, county roads, and arterials. The CHP reports aggregated injury accidents, and we disaggregated the injury accident rates into Maximum Injury Abbreviated Scale (MAIS) categories based on the share of nationwide accident data reported by the National Highway Traffic Safety Administration *(19 p. 9).* Below is the accident rate data used for this study.

Table 8. Accident Rate Assumptions

Category	Accident Rate (per million VMT)
MAIS 6 (fatal)	0.009486
MAIS 5 (critical)	0.001290
MAIS 4 (severe)	0.004975
MAIS 3 (serious)	0.017158
MAIS 2 (moderate)	0.059418
MAIS 1 (minor)	0.634997
Property Damage Only	0.801477

Source: California Highway Patrol

This BCA assumes constant accident rates for the "build" and "no build" scenarios. Thus, the only accident changes will result from changes in VMT, not a structural change to the safety conditions on the roadway network.

The benefits resulting from accident reduction are converted to monetary values using the cost of fatal and injury highway accidents recommended by the U.S. DOT *(20 pp. 1-8).* The value of 'property damage only' accidents is derived from a Federal Highway Administration *(21)* technical advisory. The following table outlines the values used as expressed in real 2010 dollars after CPI-U adjustment.

Table 9. Value of a Statistical Life and of Accidents by MAIS Category

Category	Value
Value of a Statistical Life	$ 6,102,000
MAIS 6 (fatal) – cost	$ 6,102,000
MAIS 5 (critical) – cost	$ 4,652,775
MAIS 4 (severe) – cost	$ 1,144,125
MAIS 3 (serious) – cost	$ 350,865
MAIS 2 (moderate) – cost	$ 94,581
MAIS 1 (minor) – cost	$ 12,204
MAIS 0 (property only) –cost	$ 3,790

Source: U.S. Department of Transportation

3.3 – Sustainability

The CA HSR project will create environmental and sustainability benefits by reducing air and noise pollution associated with automobile travel as there is a reduction in vehicle-miles travel from mode shifts. For noise pollution, six emissions from which to measure and monetize benefits were identified, including: carbon monoxide, nitrous oxide, particulate matter, sulfur dioxide, volatile organic compounds, and carbon dioxide.

3.3.1 Auto Emissions

Per mile emissions factors differ depending on vehicle, fuel efficiency, average speed, and driving conditions. This BCA used the California Department of Transportation's emissions factors from the California Life-cycle Benefit-Cost Analysis Model (Cal B/C) *(22).* This model provides emissions factors for automobiles and trucks at varying speeds from 5 to 65 miles per hour.

This analysis used the year 2007 and 2027 emissions factors provided for cars and trucks at an assumed speed of 35 miles per hour (see Table 10 and Table 11). Emissions factors were subsequently extrapolated to other years in order to build a dynamic time series. Consistent with the Cal B/C model's technical documentation *(23 pp. iii.60-iii.61),* CO2 and SOx were assumed to grow linearly, while the remaining factors (CO, NOX, PM10, and VOC) grew exponentially. The CAGR for 2007 to 2027 was used and applied through 2047 (a twenty year extrapolation). Beyond this point, this analysis assumed the factors to "flat line," reflecting the uncertainty of estimating emissions factors beyond this period.

Table 10. Emissions Factors From Cal B/C Model, 2007

Emissions type (grams per VMT)	Passenger Cars	Trucks
CO	4.0952	5.7648
NOX	0.4291	11.3895
PM10	0.0342	0.4438
SOX	0.0040	0.0130
VOC	0.3216	1.0098
CO2	388.20	1,348.50

Source: California Department of Transportation, Cal B/C

Table 11. Emissions Factors From Cal B/C Model, 2027

Emissions type (grams per VMT)	Passenger Cars	Trucks
CO	1.0774	1.3326
NOX	0.0883	2.4211
PM10	0.036	0.1133
SOX	0.0038	0.0134
VOC	0.1015	0.315
CO2	381.72	1396.52

Source: California Department of Transportation, Cal B/C

Emissions costs were also taken from the California Life-cycle Benefit Cost model (22). These costs were on a per-ton basis and are as follows:

Table 12. Cost of Emissions – CAL/BC

Emissions Type	Cost per ton (2010 $)
CO	$ 70
NOX	$ 16,300
PM10	$ 131,800
SOX	$ 65,800
VOC	$ 1,140
CO2	$ 37

Source: California Department of Transportation, Cal B/C

3.3.2 Auto Noise Pollution

The CA HSR investments also contribute to reductions in noise pollution by reducing VMT. This is because reductions in VMT translate to reductions in noise output by the vehicles. This BCA assumes a cost of noise of $0.001 per VMT as expressed in real 2010 dollars (after CPIU-adjustment), consistent with the National Traffic Highway and Safety Administration's figures *(19 pp. viii-60).*

3.3.3 Aviation Emissions Savings

The quantity of fuel saved in the aviation system due to HSR mode-shifts was previously quantified to calculate fuel savings. That same quantity of fuel saved can subsequently be converted into emissions to calculate the aviation emissions savings that result from CA HSR. The following emissions factors for aviation, from the United Nations *(24),* allow the flight and fuel savings to be converted into emissions:

Table 13. Emissions Factors for Aviation, Average Aircraft Takeoff/Landing Cycle and Cruising

Emission Type	Emissions per takeoff/landing cycle (kg / flight)	Emissions during cruising (kg / ton fuel)
SO2	0.80	1.00
CO	8.10	7.00
CO2	2680	3150
NOX	10.2	11.0
VOC	2.60	0.70

Source: United Nations Intergovernmental Panel on Climate Change

Emissions from takeoff/landing cycles refer to the fact that the process of takeoff plus the process of landing has its own unique emissions factors. This occurs on a per-flight basis. The cruising portion of the flight has emissions factors pertaining to the fuel usage, which was calculated previously. The same monetization factors used for auto emissions were used to monetize savings in aviation emissions.

4.0 - Economic Benefits Not Included

The following is a summary of other potential benefits that are excluded from the BCA. The ensuing discussion describes these possible benefits and explains the rationale for their exclusion.

4.1 - Fares

Fares are an economic transfer from users to the HSR operator. Because they are a pecuniary transfer, they represent neither an economic benefit nor an economic cost of the project. In this BCA, fares are excluded from both the benefit and O&M cost tabulations.

4.2 - Construction Delay

During the period of project construction there are expected to be some impacts on the roadway network due to construction, especially in and about urban areas. This would create additional delay on the roadway system during the period of construction, thereby offsetting against some travel time savings. However, the impacts are likely to be localized, and the entirety of the CA HSR project minimizes urban grade crossings. These impacts are not included in this analysis, and are assumed to be negligible in proportion to overall travel time savings.

4.3 – Land Use Impacts / Land Value Impacts

This BCA does not incorporate or monetize the land use impacts that the CA HSR project may cause. Because of the improved connectivity between urban areas, and the impacts that new stations may have on their surrounding environments, it is possible that land values may change to reflect the improvements in accessibility. Furthermore, changes in travel times may influence employment and housing patterns, creating land-use impacts throughout the region. Such changes were not included in this BCA, but are discussed in the rest of the Business Plan.

4.4 – Improved Economic Productivity

Improved travel times and reduction in time-distances along the CA HSR corridor may create shifts in employment patterns and allow workers access to more job markets that were not previously feasible. As a result, workers may seek employment in higher output work that puts their labor to the highest and best use. This has the effect of increasing overall economic productivity in the region as workers can be gainfully employed in a broader geographic job market. Such impacts, however, were excluded from this BCA as they would require detailed labor market analysis beyond the scope of the data available. Nonetheless, such impacts are discussed in the wider economic impacts analysis in this Business Plan.

5.0 - Economic Costs Included and Assumptions

In the benefit-cost analysis, the term 'cost' refers to the additional resource costs or expenditures required to implement, perpetuate, and maintain the investments associated with CA HSR.

The BCA uses project costs that have been estimated for CA HSR on an annual basis. Operations and maintenance costs were initially express in real 2009 dollars; rehabilitation costs were initially expressed in real 2008 dollars; and capital costs were initially expressed in real 2009 dollars. All costs were converted to real 2010 dollars based on CPI-U adjustments.

5.1 - Initial Project Investment Costs

Initial project investment costs include engineering and design, construction, acquisition of right-of-way, vehicles, other capital investments, and contingency factors.

Outlays spent for the acquisition of real assets are excluded from total costs in this BCA. This is because when the government acquires a real asset, is considered an asset purchase and not a cost. The Authority would be in possession of tangible assets that, at least historically, had not depreciated in value. Thus, the costs of right of way and other property costs are excluded from this analysis. However, this BCA assumes that 20 percent of right of way costs are for administrative and professional services and those costs are included.

The overall project capital investment costs are typically treated in one of two basic ways. The first, and most common, is to treat the project costs as up-front costs coinciding with the actual project expenditures on a pay-as-you go basis. This approach excludes financing costs from long-term borrowing as part of the investment expenditures subject to present value calculations.

An alternative approach would consider the proposed financial plan for the investments, when the plan involves long-term debt that is repaid over time with interest, and account for the financing costs as the debt is repaid. The two approaches yield essentially the same results for the discounted present value of the project investment costs.[1] As a result, the former pay-as-you-go assumption is usually adopted in recognition that a detailed financial plan typically would not yet be available at the time when a BCA of project alternatives is undertaken.

[1] A small difference may result from financing costs such as the underwriter's fees which would not be part of pay-as-you-go investment.

To understand why debt service costs over time for financed investments equate to the same present value as up-front, pay-as-you-go investments, note that debt service amounts are expressed in nominal dollars, calculated using a nominal interest rate that includes both real and inflationary components. Because BCA typically accounts for all dollar amounts in constant dollars of a single year (e.g., 2010 dollars), it is necessary to convert the stream of debt service payments into constant dollars. However, once inflation is extracted from the nominal debt service payments, the remaining debt service is simply a stream of principal repayments and real interest payments.[2] Converting this stream of real debt service payments to its present value using a real discount rate cancels out the real interest paid over time, leaving the sum of the principal payments — the original level of investment. Put another way, the long term real cost of capital for public highway investments in a relatively risk free environment is essentially equal to the real discount rate.

5.2 - Annual Operating and Maintenance Costs

The annual cost of operating and maintaining the proposed CA HSR are included in the analysis. Operations and maintenance activities apply to several assets, including track, rolling stock, stations, overhead, customer service, staff and other operations. Operating and maintenance costs are assumed to begin at the start of the year immediately following the completion of a sub-phase. This is consistent with benefits beginning at the same point.

O&M costs were provided for year 2030, much in the same way that ridership was provided for the same year. These costs grew at 60 percent of the growth of ridership, so if ridership grew 1 percent, O&M costs grew 0.6 percent. Finally, O&M costs were phased in such that the marginal O&M costs of a specific sub-phase was not experienced until that sub-phase was completed.

The operating costs reported were the net operating costs, or the costs above and beyond the "no build" scenario, which presumes continuation of existing Amtrak San Joaquin service and its associated costs. The operating costs do not net out the operating costs of other Amtrak lines that may cease service with the introduction of CA HSR. Doing so would decrease the net O&M costs for this project further.

5.3 - Periodic Capital Equipment Replacement Costs and Major Rehabilitation

Several types of initial asset investments will need to be replaced or rehabilitated during the evaluation period. It is assumed that the following have a 100 year life-cycle before needing full replacement equal to the original costs: civil infrastructure; structures; track; stations, terminals and intermodal; and support facilities, yards, shops, and administrative buildings.

Communications, signaling, and electric traction were assumed to have a 30 year life-cycle. Vehicles were assumed to have a 45 year life cycle. Other cost categories such as right of way and professional services do not have a feasible life-cycle and are not subject to rehabilitation costs.

[2] Assuming the project can secure debt with a solid credit rating such that there is no material risk component also factored into the borrowing interest rate. An interest rate premium for risk could result in a higher net present value cost for the project under debt financing than pay-as-you go. However, the use of tax-exempt debt with lower nominal interest rates than taxable debt may offset the real increase attributable to credit risk.

Because this project consisted of sub-phases, with different components reflecting each sub-phase being built in different years, the rehabilitations costs reflect that. Thus, the clock for rehabilitation begins upon the end of construction of each sub-phase individually. In effect, there are four "clocks" reflecting four rehabilitation schedules, one for each sub-phase.

5.4 – Residual Value

For assets aside from real estate (discussed above), this BCA assumes that the tangible assets depreciate linearly over their life-cycle. These are the same cost categories that have a life-cycle and are subject to major rehabilitation. Further, the value of the asset is increased every time there is major rehabilitation work by the cost of the rehabilitation work.

Since this analysis ends in year 2080, whatever value is remaining in the asset is attributed as a one-time, one year cost-offset (or negative cost). This reflects the fact that the agency has tangible assets with remaining value in them.

6.0 - Key Benefit-Cost Evaluation Measures

There are three common benefit-cost evaluation measures, each tailored to compare benefits and costs from different perspectives.

The benefit-cost analysis converts potential gains and losses from the proposed investment into monetary units and compares them on the basis of economic efficiency, i.e., net present value (NPV). For example, NPV = PVB (present value of benefits) - PVC (present value of costs); where:

$$PVB = \sum_{t=0}^{T} B_t / (1+r)^t; \text{ and } PVC = \sum_{t=0}^{T} C_t / (1+r)^t$$

Equation 1

And the NPV of a project can be represented as:

$$NPV = \sum_{t=0}^{T} (B_t - C_t)/ (1+r)^t,$$

Equation 2

where B_t and C_t are the benefits and costs, respectively, of a project in year t; r is the real discount rate; and T is the time horizon (evaluation period). In essence, NPV gives the magnitude of the project's economic feasibility in terms of net benefits (benefits minus costs) discounted to present values using the real discount rate assumption. Under this criterion, a scenario with an NPV greater than zero may be considered "economically feasible." The NPV provides some perspective on the overall dollar magnitude of benefits not reflected by the other two measures.

6.1 Economic Rate of Return

The Economic Rate of Return (ERR) is the discount rate that makes the present value of all benefits just equal to the present value of all costs, i.e., the real discount rate at which the project's NPV is zero and it's benefit-cost is unity. The ERR measures the social or economic return on investment. As an evaluation measure, it allows comparison of the proposed investment package with other similar packages and/or alternative uses of investment funds that may have different costs, different benefit flows, and/or different timing. Note that the ERR is interpreted as a real rate of return (after accounting for inflation), since the assumption is that benefits and costs are expressed in constant dollars. As such, it should not be directly compared with investment returns calculated from inflated or nominal future year dollars. In some cases, a threshold value for the ERR may be established where exceeding that threshold results in the determination of an economically justified project.

6.2 Benefit/Cost Ratio

The evaluation also estimates the benefit-cost ratio; where the present value of incremental benefits divided by the present value of incremental costs yields the benefit-cost ratio (B/C Ratio), i.e., B/C Ratio = PVB / PVC. In essence, the B/C Ratio expresses the relation of discounted benefits to discounted costs as a measure of the extent by which a project's benefits either exceed or fall short of their associated costs. For example, a B/C ratio of 1.5 indicates that the project generates $1.5 of benefits per $1 of cost. As such, a ratio greater than 1 is necessary for the project to be economically worthwhile (feasible). The B/C Ratio can be useful when the objective is to prioritize or rank projects or portfolios of projects with the intent to decide how to best allocate an established capital budget, assuming equivalent classification of benefits and costs.

7.0 – CA HSR BENEFIT-COST ANALYSIS RESULTS

7.1 - Results in Brief

There were two "scenarios" conducted for this analysis. They are:

- Scenario 1 (low capital cost)
- Scenario 2 (high capital cost)

All scenarios presume a 4 percent discount rate. The results for each scenario are outlined below in Table 14:

Table 14. Benefit Cost Analysis Summary Results

Scenario	Net Present Value (NPV)	Economic Rate of Return (ERR)	Benefit Cost Ratio (B/C)
Scenario 1 (low capital cost)	$39.8 billion	7.10%	1.78
Scenario 2 (high capital cost)	$30.6 billion	6.22%	1.57

7.2 - Benefits by Category

Table 15 below outlines the overall benefits and costs, by category, for each scenario:

Table 15. Summary of Benefits and Costs by Scenario (Discounted 2010 $)

	Scenario 1 (low capital cost)	Scenario 2 (high capital cost)
Benefits		
Roads and Highways		
Highway User Travel Time Savings	$28,125,772,927	$26,430,574,833
Highway User Fuel Savings	$1,918,477,064	$1,839,233,067
Highway User Non-fuel O&M Savings	$9,292,366,381	$8,687,803,515
Oil Import Savings	$954,370,665	$885,824,727
Reduction in Pavement Damages	$35,037,408	$32,749,961
CO2 Emissions Savings	$1,153,163,925	$1,078,907,653
Non CO2 Emissions Savings	$471,708,939	$437,761,912
Noise Savings	$68,734,749	$64,222,378
Road Fatality Reductions	$3,978,518,838	$3,717,332,823
Road Injury Reductions	$2,136,415,037	$1,996,161,402
Vehicle Property Damage Reductions	$208,788,562	$195,081,789
HSR Mode Shift Benefits		
Travel Time Savings for HSR Mode Shift Users	$19,901,477,467	$18,275,992,758
HSR Mode Shift User reliability benefits	$10,016,373,676	$9,198,270,483
Productivity Increases from Transfers to HSR	$7,661,078,436	$7,035,347,715
Reductions in Parking Infrastructure Needs	$337,876,240	$310,279,662
Aviation Savings		
Operator Savings from Delay Reductions (non-fuel)	$346,119,311	$319,857,325
Fuel Savings, aviation	$2,867,615,696	$2,683,993,681
Air System Savings from Propagated Delay	$173,059,656	$159,928,662
Air Passenger Travel Time Savings from Delay Reduction	$155,085,338	$143,318,155
Aviation CO2 Reductions	$275,105,057	$252,387,044
Aviation Non-CO2 Emissions Reductions	$581,575,160	$533,549,025
Total Benefits	**$90,658,720,530**	**$84,278,578,571**

	Scenario 1 (low capital cost)	Scenario 2 (high capital cost)
Costs		
Capital Costs, less real estate	$37,242,151,067	$41,166,331,011
Rehabilitation Costs	$954,689,191	$855,420,976
Net O&M Costs	$13,934,031,946	$13,106,498,268
Subtotal Costs	$52,130,872,203	$55,128,250,254
Residual Value	$1,246,640,709	$1,455,624,125
Net Costs (less residual value)	**$50,884,231,495**	**$53,672,626,129**

About 90.1 percent of all CA HSR benefits are attributable to economic competitiveness. Safety benefits are the next largest category, safety, is 7.0 percent, and the remaining three categories comprise less than 3 percent. While the absolute numbers per scenario, the proportions remain almost identical across both scenarios. The (discounted) present values of all benefits that were quantified are shown in Figure 2.

Figure 1. Benefit Shares by DOT Category – Discounted Present Value (2010 $), All Scenarios (approximate)

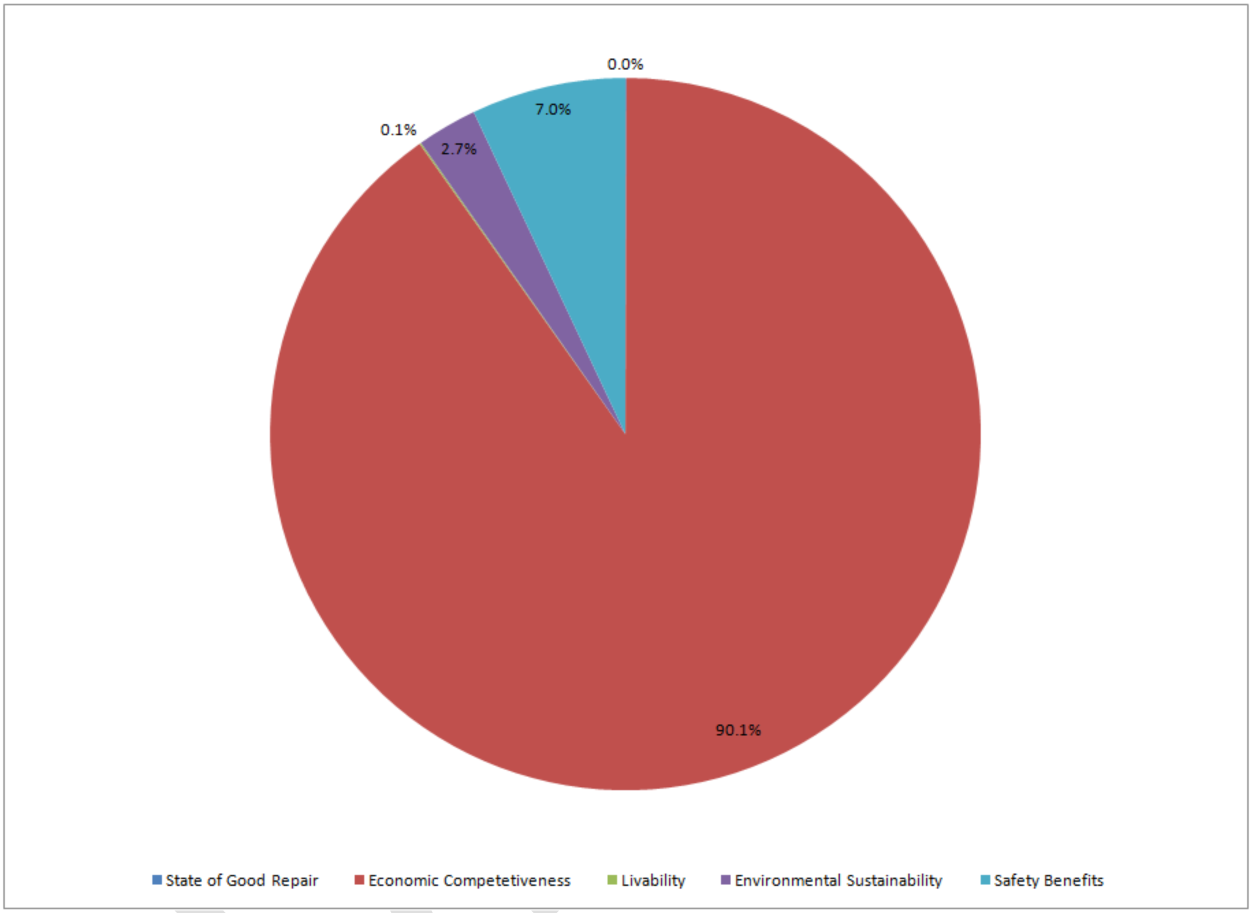
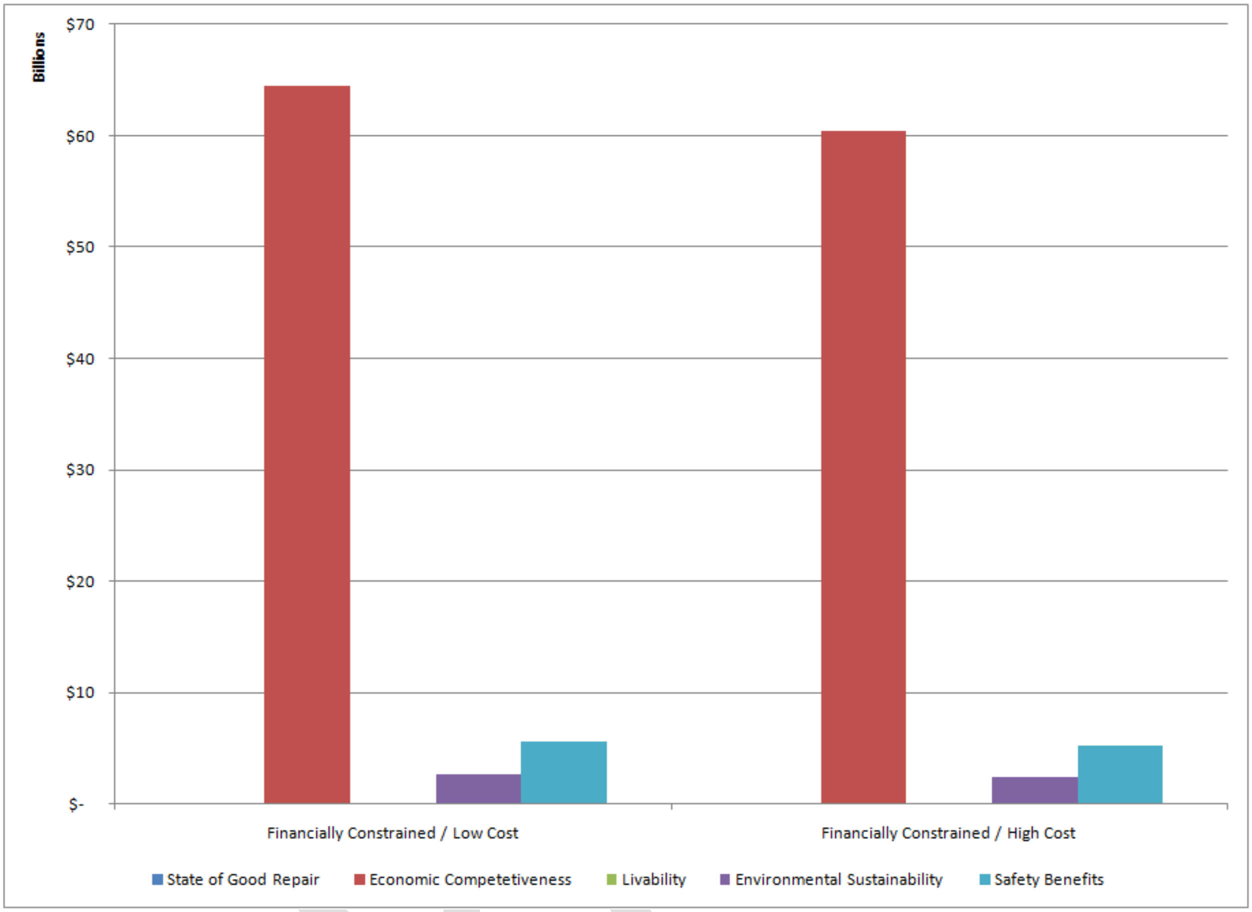


Figure 2. Benefits Amounts – Discounted Present Value (2010 $)



7.3 - Costs over Time

Figure 3 to Figure 4 present the capital expenditures over time, expressed in constant 2010 dollars before present value discounting.

Figure 3. Capital and Rehabilitation Expenditures in 2010 Dollars before Present Value Discounting, Scenario 1

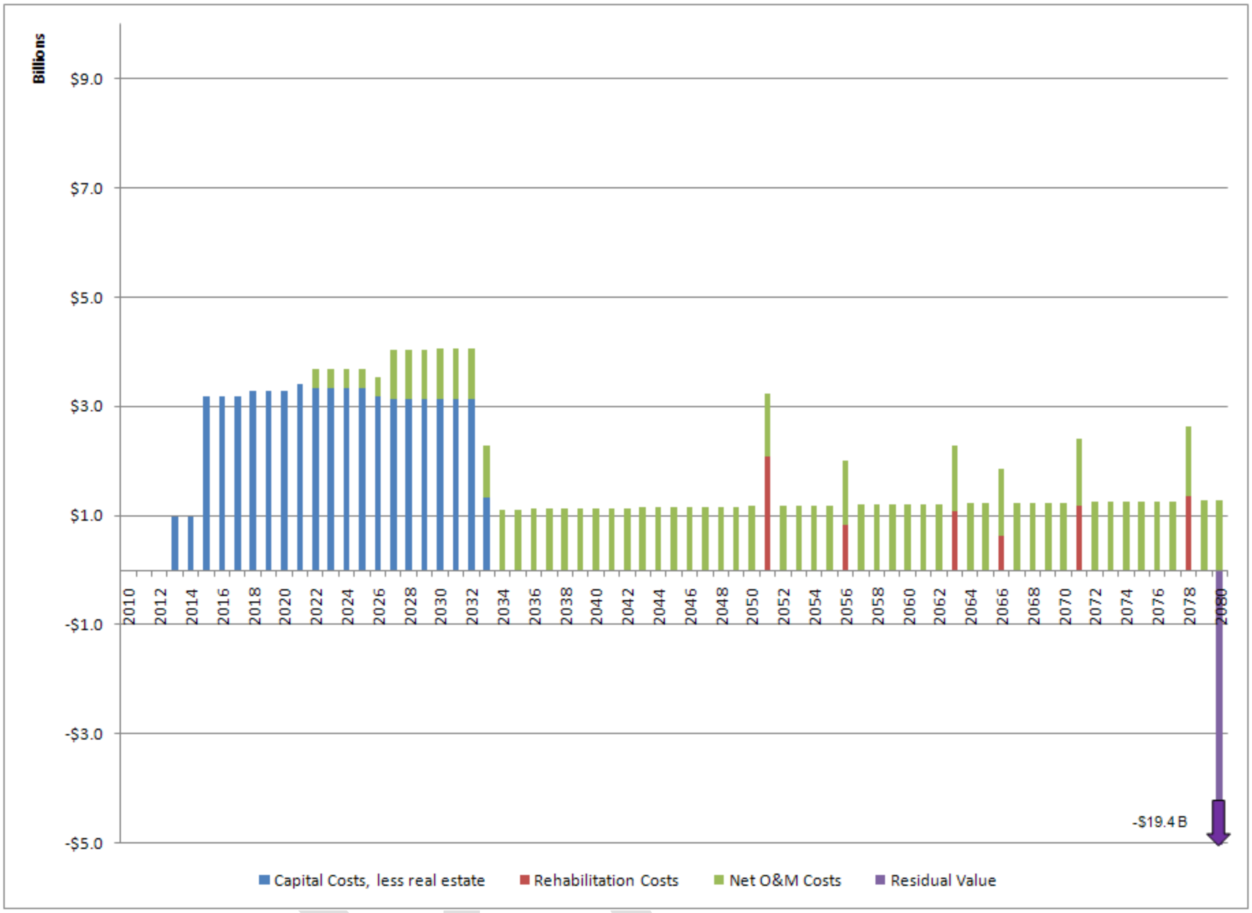
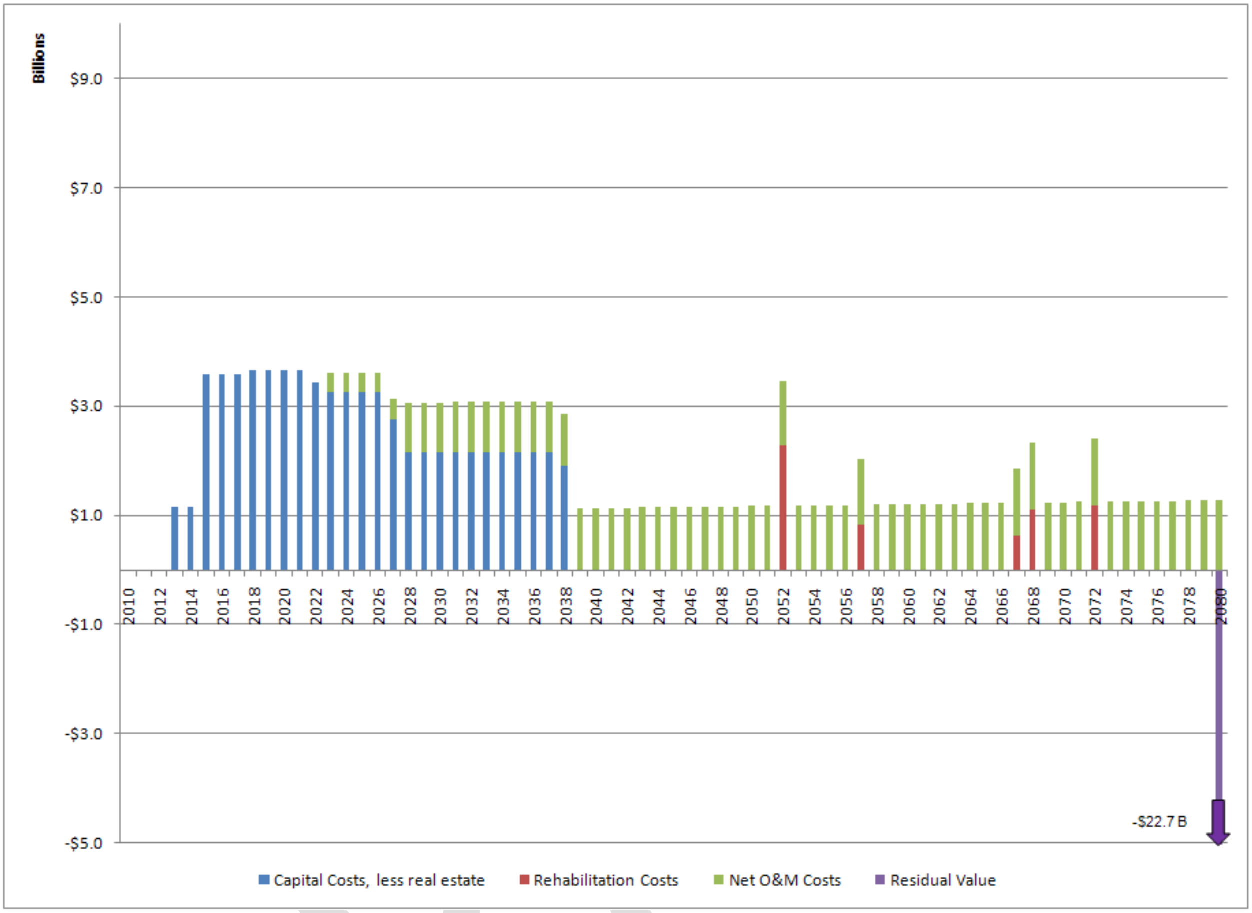


Figure 4. Capital and Rehabilitation Expenditures in 2010 Dollars before Present Value Discounting, Scenario 2



7.4 Cumulative Benefits and Costs

Figure 5 and Figure 6 present cumulative present value of benefits with the cumulative present value of costs over time for the four scenarios. These discounted benefits and costs show at which point the benefits exceed costs. For the four scenarios, they are as follows:

- Scenario 1: between 2046 and 2047
- Scenario 2: between 2053 and 2054

Figure 5. Cumulative Benefits and Costs in 2010 Dollars (Discounted at 4 percent), Scenario 1

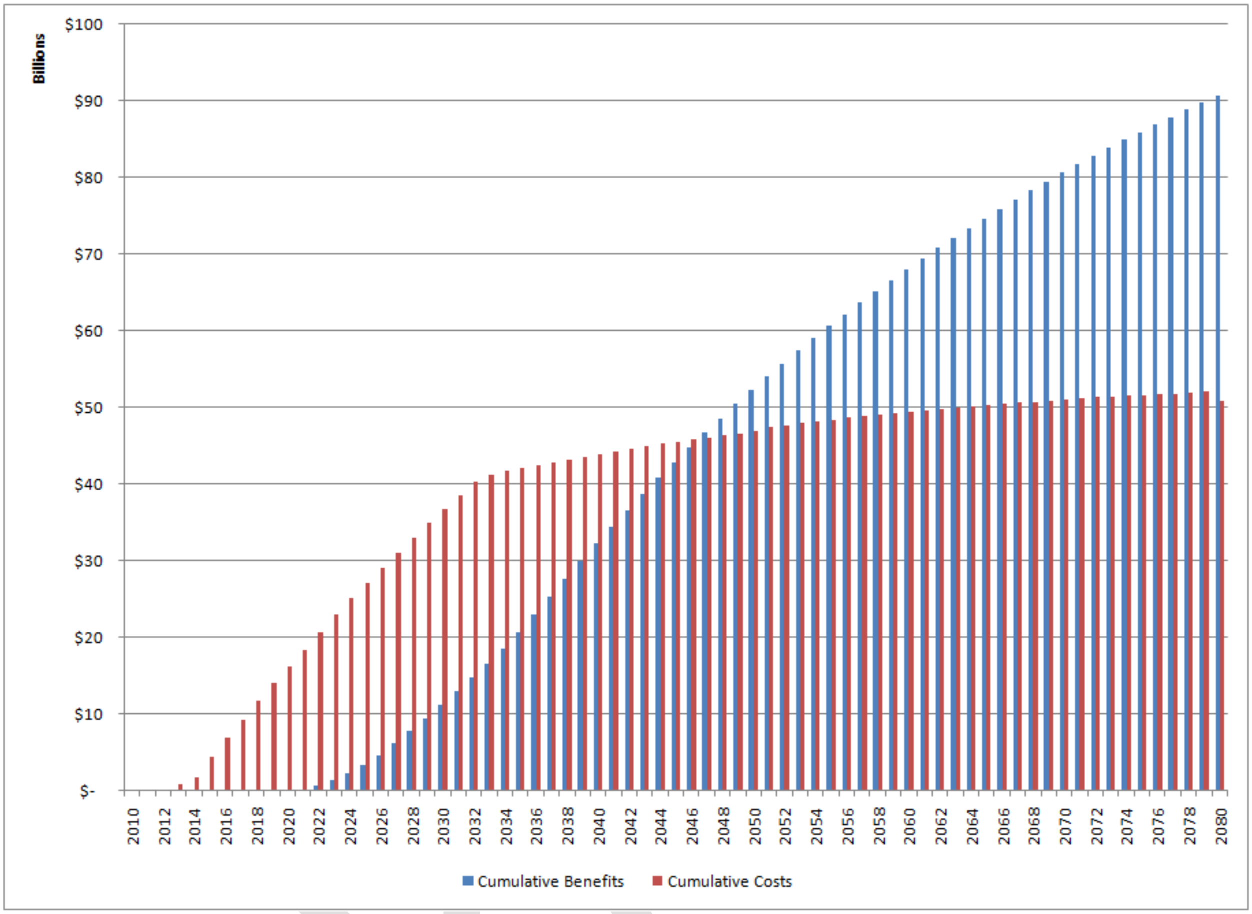
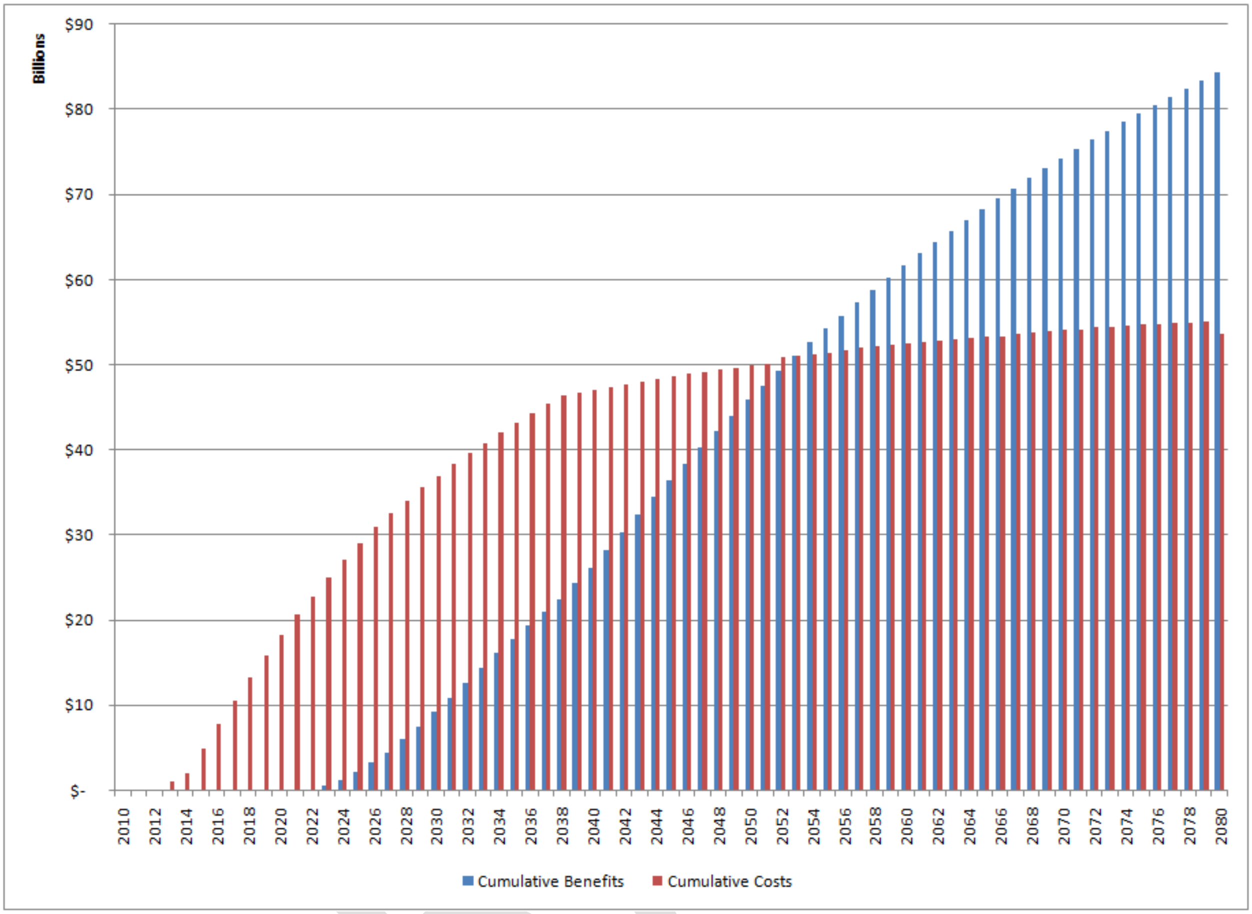


Figure 6. Cumulative Benefits and Costs in 2010 Dollars (Discounted at 4 percent), Scenario 2



8.0 Conclusion

This analysis shows that the anticipated quantifiable benefits from the CA HSR project exceed their anticipated costs regardless of the phasing or the high/low cost scenarios presented. It is important to note this analysis does not include all of the potential benefits that HSR investments will contribute to the region. The value of providing a transportation service that is the first of its kind in the United States, in one of America's most populous states, is a substantial structural change to the transportation and land use system that will bring economic benefits for the future.

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